

APPENDIX A-2 TO PART 60—TEST
METHODS 2G THROUGH 3C

Method 2G—Determination of Stack Gas Velocity and Volumetric Flow Rate With Two-Dimensional Probes

Method 2H—Determination of Stack Gas Velocity Taking Into Account Velocity Decay Near the Stack Wall

Method 3—Gas analysis for the determination of dry molecular weight

Method 3A—Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedure)

Method 3B—Gas analysis for the determination of emission rate correction factor or excess air

Method 3C—Determination of carbon dioxide, methane, nitrogen, and oxygen from stationary sources

The test methods in this appendix are referred to in §60.8 (Performance Tests) and §60.11 (Compliance With Standards and Maintenance Requirements) of 40 CFR part 60, subpart A (General Provisions). Specific uses of these test methods are described in the standards of performance contained in the subparts, beginning with Subpart D.

Within each standard of performance, a section title “Test Methods and Procedures” is provided to: (1) Identify the test methods to be used as reference methods to the facility subject to the respective standard and (2) identify any special instructions or conditions to be followed when applying a method to the respective facility. Such instructions (for example, establish sampling rates, volumes, or temperatures) are to be used either in addition to, or as a substitute for procedures in a test method. Similarly, for sources subject to emission monitoring requirements, specific instructions pertaining to any use of a test method as a reference method are provided in the subpart or in Appendix B.

Inclusion of methods in this appendix is not intended as an endorsement or denial of their applicability to sources that are not subject to standards of performance. The methods are potentially applicable to other sources; however, applicability should be confirmed by careful and appropriate evaluation of the conditions prevalent at such sources.

The approach followed in the formulation of the test methods involves specifications for equipment, procedures, and performance. In concept, a performance specification approach would be preferable in all methods because this allows the greatest flexibility to the user. In practice, however, this approach is impractical in most cases because performance specifications cannot be established. Most of the methods described herein, therefore, involve specific equipment specifications and procedures, and only a few

methods in this appendix rely on performance criteria.

Minor changes in the test methods should not necessarily affect the validity of the results and it is recognized that alternative and equivalent methods exist. Section 60.8 provides authority for the Administrator to specify or approve (1) equivalent methods, (2) alternative methods, and (3) minor changes in the methodology of the test methods. It should be clearly understood that unless otherwise identified all such methods and changes must have prior approval of the Administrator. An owner employing such methods or deviations from the test methods without obtaining prior approval does so at the risk of subsequent disapproval and retesting with approved methods.

Within the test methods, certain specific equipment or procedures are recognized as being acceptable or potentially acceptable and are specifically identified in the methods. The items identified as acceptable options may be used without approval but must be identified in the test report. The potentially approvable options are cited as “subject to the approval of the Administrator” or as “or equivalent.” Such potentially approvable techniques or alternatives may be used at the discretion of the owner without prior approval. However, detailed descriptions for applying these potentially approvable techniques or alternatives are not provided in the test methods. Also, the potentially approvable options are not necessarily acceptable in all applications. Therefore, an owner electing to use such potentially approvable techniques or alternatives is responsible for: (1) assuring that the techniques or alternatives are in fact applicable and are properly executed; (2) including a written description of the alternative method in the test report (the written method must be clear and must be capable of being performed without additional instruction, and the degree of detail should be similar to the detail contained in the test methods); and (3) providing any rationale or supporting data necessary to show the validity of the alternative in the particular application. Failure to meet these requirements can result in the Administrator’s disapproval of the alternative.

METHOD 2G—DETERMINATION OF STACK GAS
VELOCITY AND VOLUMETRIC FLOW RATE
WITH TWO-DIMENSIONAL PROBES

NOTE: This method does not include all of the specifications (e.g., equipment and supplies) and procedures (e.g., sampling) essential to its performance. Some material has been incorporated from other methods in this part. Therefore, to obtain reliable results, those using this method should have a thorough knowledge of at least the following

additional test methods: Methods 1, 2, 3 or 3A, and 4.

1.0 Scope and Application

1.1 This method is applicable for the determination of yaw angle, near-axial velocity, and the volumetric flow rate of a gas stream in a stack or duct using a two-dimensional (2-D) probe.

2.0 Summary of Method

2.1 A 2-D probe is used to measure the velocity pressure and the yaw angle of the flow velocity vector in a stack or duct. Alternatively, these measurements may be made by operating one of the three-dimensional (3-D) probes described in Method 2F, in yaw determination mode only. From these measurements and a determination of the stack gas density, the average near-axial velocity of the stack gas is calculated. The near-axial velocity accounts for the yaw, but not the pitch, component of flow. The average gas volumetric flow rate in the stack or duct is then determined from the average near-axial velocity.

3.0 Definitions

3.1 *Angle-measuring Device Rotational Offset (R_{ADO})*. The rotational position of an angle-measuring device relative to the reference scribe line, as determined during the pre-test rotational position check described in section 8.3.

3.2 *Calibration Pitot Tube*. The standard (Prandtl type) pitot tube used as a reference when calibrating a probe under this method.

3.3 *Field Test*. A set of measurements conducted at a specific unit or exhaust stack/duct to satisfy the applicable regulation (e.g., a three-run boiler performance test, a single-or multiple-load nine-run relative accuracy test).

3.4 *Full Scale of Pressure-measuring Device*. Full scale refers to the upper limit of the measurement range displayed by the device. For bi-directional pressure gauges, full scale includes the entire pressure range from the lowest negative value to the highest positive value on the pressure scale.

3.5 *Main probe*. Refers to the probe head and that section of probe sheath directly attached to the probe head. The main probe sheath is distinguished from probe extensions, which are sections of sheath added onto the main probe to extend its reach.

3.6 “*May*,” “*Must*,” “*Shall*,” “*Should*,” and the imperative form of verbs.

3.6.1 “*May*” is used to indicate that a provision of this method is optional.

3.6.2 “*Must*,” “*Shall*,” and the imperative form of verbs (such as “record” or “enter”) are used to indicate that a provision of this method is mandatory.

3.6.3 “*Should*” is used to indicate that a provision of this method is not mandatory, but is highly recommended as good practice.

3.7 *Method 1*. Refers to 40 CFR part 60, appendix A, “Method 1—Sample and velocity traverses for stationary sources.”

3.8 *Method 2*. Refers to 40 CFR part 60, appendix A, “Method 2—Determination of stack gas velocity and volumetric flow rate (Type S pitot tube).”

3.9 *Method 2F*. Refers to 40 CFR part 60, appendix A, “Method 2F—Determination of stack gas velocity and volumetric flow rate with three-dimensional probes.”

3.10 *Near-axial Velocity*. The velocity vector parallel to the axis of the stack or duct that accounts for the yaw angle component of gas flow. The term “near-axial” is used herein to indicate that the velocity and volumetric flow rate results account for the measured yaw angle component of flow at each measurement point.

3.11 *Nominal Velocity*. Refers to a wind tunnel velocity setting that approximates the actual wind tunnel velocity to within ± 1.5 m/sec (± 5 ft/sec).

3.12 *Pitch Angle*. The angle between the axis of the stack or duct and the pitch component of flow, i.e., the component of the total velocity vector in a plane defined by the traverse line and the axis of the stack or duct. (Figure 2G-1 illustrates the “pitch plane.”) From the standpoint of a tester facing a test port in a vertical stack, the pitch component of flow is the vector of flow moving from the center of the stack toward or away from that test port. The pitch angle is the angle described by this pitch component of flow and the vertical axis of the stack.

3.13 *Readability*. For the purposes of this method, readability for an analog measurement device is one half of the smallest scale division. For a digital measurement device, it is the number of decimals displayed by the device.

3.14 *Reference Scribe Line*. A line permanently inscribed on the main probe sheath (in accordance with section 6.1.5.1) to serve as a reference mark for determining yaw angles.

3.15 *Reference Scribe Line Rotational Offset (R_{SLO})*. The rotational position of a probe’s reference scribe line relative to the probe’s yaw-null position, as determined during the yaw angle calibration described in section 10.5.

3.16 *Response Time*. The time required for the measurement system to fully respond to a change from zero differential pressure and ambient temperature to the stable stack or duct pressure and temperature readings at a traverse point.

3.17 *Tested Probe*. A probe that is being calibrated.

3.18 *Three-dimensional (3-D) Probe*. A directional probe used to determine the velocity

pressure and the yaw and pitch angles in a flowing gas stream.

3.19 *Two-dimensional (2-D) Probe.* A directional probe used to measure velocity pressure and yaw angle in a flowing gas stream.

3.20 *Traverse Line.* A diameter or axis extending across a stack or duct on which measurements of velocity pressure and flow angles are made.

3.21 *Wind Tunnel Calibration Location.* A point, line, area, or volume within the wind tunnel test section at, along, or within which probes are calibrated. At a particular wind tunnel velocity setting, the average velocity pressures at specified points at, along, or within the calibration location shall vary by no more than 2 percent or 0.3 mm H₂O (0.01 in. H₂O), whichever is less restrictive, from the average velocity pressure at the calibration pitot tube location. Air flow at this location shall be axial, i.e., yaw and pitch angles within $\pm 3^\circ$ of 0° . Compliance with these flow criteria shall be demonstrated by performing the procedures prescribed in sections 10.1.1 and 10.1.2. For circular tunnels, no part of the calibration location may be closer to the tunnel wall than 10.2 cm (4 in.) or 25 percent of the tunnel diameter, whichever is farther from the wall. For elliptical or rectangular tunnels, no part of the calibration location may be closer to the tunnel wall than 10.2 cm (4 in.) or 25 percent of the applicable cross-sectional axis, whichever is farther from the wall.

3.22 *Wind Tunnel with Documented Axial Flow.* A wind tunnel facility documented as meeting the provisions of sections 10.1.1 (velocity pressure cross-check) and 10.1.2 (axial flow verification) using the procedures described in these sections or alternative procedures determined to be technically equivalent.

3.23 *Yaw Angle.* The angle between the axis of the stack or duct and the yaw component of flow, i.e., the component of the total velocity vector in a plane perpendicular to the traverse line at a particular traverse point. (Figure 2G-1 illustrates the "yaw plane.") From the standpoint of a tester facing a test port in a vertical stack, the yaw component of flow is the vector of flow moving to the left or right from the center of the stack as viewed by the tester. (This is sometimes referred to as "vortex flow," i.e., flow around the centerline of a stack or duct.) The yaw angle is the angle described by this yaw component of flow and the vertical axis of the stack. The algebraic sign convention is illustrated in Figure 2G-2.

3.24 *Yaw Nulling.* A procedure in which a Type-S pitot tube or a 3-D probe is rotated about its axis in a stack or duct until a zero differential pressure reading ("yaw null") is obtained. When a Type S probe is yaw-nulled, the rotational position of its impact port is 90° from the direction of flow in the stack or duct and the ΔP reading is zero.

When a 3-D probe is yaw-nulled, its impact pressure port (P_1) faces directly into the direction of flow in the stack or duct and the differential pressure between pressure ports P_2 and P_3 is zero.

4.0 Interferences. [Reserved]

5.0 Safety

5.1 This test method may involve hazardous operations and the use of hazardous materials or equipment. This method does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to establish and implement appropriate safety and health practices and to determine the applicability of regulatory limitations before using this test method.

6.0 Equipment and Supplies

6.1 *Two-dimensional Probes.* Probes that provide both the velocity pressure and the yaw angle of the flow vector in a stack or duct, as listed in sections 6.1.1 and 6.1.2, qualify for use based on comprehensive wind tunnel and field studies involving both inter- and intra-probe comparisons by multiple test teams. Each 2-D probe shall have a unique identification number or code permanently marked on the main probe sheath. Each probe shall be calibrated prior to use according to the procedures in section 10. Manufacturer-supplied calibration data shall be used as example information only, except when the manufacturer calibrates the probe as specified in section 10 and provides complete documentation.

6.1.1 *Type S (Stausscheibe or reverse type) pitot tube.* This is the same as specified in Method 2, section 2.1, except for the following additional specifications that enable the pitot tube to accurately determine the yaw component of flow. For the purposes of this method, the external diameter of the tubing used to construct the Type S pitot tube (dimension D, in Figure 2-2 of Method 2) shall be no less than 9.5 mm (3/8 in.). The pitot tube shall also meet the following alignment specifications. The angles α_1 , α_2 , β_1 , and β_2 , as shown in Method 2, Figure 2-3, shall not exceed $\pm 2^\circ$. The dimensions w and z , shown in Method 2, Figure 2-3 shall not exceed 0.5 mm (0.02 in.).

6.1.1.1 *Manual Type S probe.* This refers to a Type S probe that is positioned at individual traverse points and yaw nulled manually by an operator.

6.1.1.2 *Automated Type S probe.* This refers to a system that uses a computer-controlled motorized mechanism to position the Type S pitot head at individual traverse points and perform yaw angle determinations.

6.1.2 *Three-dimensional probes used in 2-D mode.* A 3-D probe, as specified in sections 6.1.1 through 6.1.3 of Method 2F, may, for the